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ENTRAINED AIR IN LUBRICATING OILS

W.J. Janis and V. Rakchaev

Apparatus for Gas Bubble Separation Time, ASTM D 3427, was assembled and standardized. New and used ISO 32 and ISO 46 steam turbine lubricating oils and new seal oils were tested for their gas bubble separation time. New ISO 32 steam turbine oils had better air release properties than ISO 46 grade oils, primarily because of the lower viscosity of the ISO 32 products. Additive-free, ISO 32 grade seal oils had air release values similar to those of new ISO 32 turbine oils. A comparison of air release and foaming tendency results for 11 samples indicated no relationship between the two characteristics.

job	file	date	report no.
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1.0 INTRODUCTION

Excessive entrained air in lubricating oils can reduce lubrication effectiveness, contribute to cavitation in centrifugal pumps in lubricating oil systems and accelerate oil oxidation. It can also affect oil compressibility and therefore interfere with the rapid response required for the operation of hydraulic or control systems.

Wear of high speed thrust pads in flooded chambers is sometimes the result of high speed thrust collars causing the formation of air-filled vortices between adjacent thrust pads. These vortices increase until the oil film at the leading edge of the pads collapses and the pads wear until the oil film is re-established. The formation of vortices is cyclic, is promoted by the presence of air bubbles, and can be suppressed by a high chamber pressure.

Excessive aeration of lubricating oils can also lead to rapid air compression and therefore localized oil temperature increases in some applications. The high temperature results in the formation of micron size carbon particles which tend to remain in suspension and give the oil a black appearance, although the bulk of the oil is not seriously degraded.

The ability of entrained air or other gases to separate from oil can be measured by American Society for Testing and Materials (ASTM) test method D 3427, " Gas Bubble Separation Time of Petroleum Oils ", also known as Institute of Petroleum (IP) test method IP 313, "Air Release Value". The gas bubble separation time or air release value determined by ASTM D 3427 is a measure of the time in minutes required for air entrained in the oil to reduce to 0.2% of the initial oil volume under specific test conditions. Dissolved air initially present in the sample plays

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no role in the air entrainment test, as the separation time is calculated on a difference between two over-saturated states: (1) the maximum entrained value after 7 minutes of continuous blowing; and (2) 0.2% free air in the sample.

This report discusses air entrainment tests performed on a variety of new and in-service turbine oils, in-service boiler feed pump (BFP) oils, and new seal oils, and presents a comparison of air entrainment and foam test results for a limited set of in-service turbine lubricant samples. The tests provide baseline data for fluids whose specifications may eventually include an air entrainment requirement, should field experience show this to be necessary.

Test Methods and Results

Air entrainment test results for 34 oil samples and foam test results for 11 oil samples were determined by ASTM test methods D 3427 @ 50°C and modified D 892 @ 25°C, respectively, and are presented in Appendix I, Tables 1-4.

Discussion

(A) New Steam Turbine Oils

Air entrainment test results for new ISO 32 and 46 steam turbine lubricating oils (STOs) from Canadian suppliers (Table 1) indicate that Sunvis 916 and 925 have considerably higher air entrainment values than their ISO 32 and 46 counterparts. The Teresso 46 grade has an air release value approximately midway between the high value of Sunvis 925 and the lower values of the other STO 46 oils tested.

(B) Thermal Generating Station (TGS) In-Service Oils

As shown in Table 2, in-service ISO 46 STOs from the main turbine units and boiler feed pumps (BFPs) at Nanticoke TGS have similar air entrainment values (within the repeatability of the test method) under different service conditions. However, the Table 2 entrainment times for Thunder Bay TGS and Atikokan TGS, while similar, are considerably below those of the Nanticoke samples.

The Thunder Bay/Atikokan air release values are similar to that of new Teresso 46 (Table 1) while the Nanticoke results are higher than any of the new turbine oils tested, except for the Sunvis product. The Nanticoke samples tested were not Sunvis material and the increase in air entrainment value at Nanticoke is believed due to service conditions.

(C) Nuclear Generating Station (NGS) In-Service Oils

The ISO 32 STO from Bruce NGS "B" (Table 2) , sampled in August, 1983, showed a higher tendency to entrain air than new ISO 32 oils, again with the exception of the Sunvis product not in use at that station.

The ISO 46 STOs from Pickering NGS (Table 2) showed air entrainment values similar to those of the Nanticoke station and these values are also higher than the air entrainment values for the corresponding new material, presumably due to service conditions.

(D) New Seal Oils for Bruce Heavy Water Plant (BHWP)

As shown in Table 3, new ISO grade 32 oils of the type used as sealing oils (OH Specification M-651-84) at BHWP had air release values equivalent to those of new grade 32 turbine oils. This was expected as the two types of oil have the same viscosity.

(E) Air Release/Foam Test Comparison

Of the 10 foam test results reported in Table 2 for oils from service, only 1 oil, from Unit 1 at Nanticoke TGS, showed any residual foam after 10 minutes standing. No relations between the gas release times at 50°C and the foam volumes at 25°C were indicated by a comparison of the 10 sets of test results.

(F) Air Entrainment Test Reproducibility

In 1984 tests were carried out on 3 special samples of Teresso 46 oil from Imperial Oil to determine the reproducibility of gas bubble separation time test results obtained by Imperial Oil Research, Sarnia and the Petroleum Products Laboratory at Ontario Hydro Research. The results of Table 4 show that the test results are well within the reproducibility of test method ASTM D 3427.

Conclusions

- (1) Gas bubble separation times at 50°C for new STO 32 oils were lower than those of new STO 46 oils because of the former's lower viscosity.
- (2) STO 32 and 46 oils from service have poorer air release properties than new oils, except for the new Sunvis products. Sunvis oils have not been in service at Ontario Hydro for a sufficient time for a valid comparison between in service and new oil air entrainment characteristics to be made.
- (3) A comparison of 10 sets of test results did not indicate any relationship between air release time and foaming tendency.

- (4) Air entrainment test results on new seal oils were similar to those for new turbine oils of the same viscosity range.

Recommendation

- (1) Additional new and used steam turbine oils should be tested for their gas bubble separation times to provide more extensive data for possible inclusion of an air entrainment requirement in Ontario Hydro Specification M-332-M-85 for STO 32 and STO 46 oils - should future developments demonstrate the need for such a change. Oil samples from Thermal and Nuclear generating stations have already been obtained for this purpose.

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Appendix I

Air Release and Foam Test Data

The reported gas separation test results in the following Tables 1 to 3 meet the following repeatability conditions of ASTM D 3427:

- (1) plus or minus 0.7 for results less than 5 minutes;
- (2) plus or minus 1.3 for results from 5 to 10 minutes; and
- (3) plus or minus 1.6 for results from 10 to 15 minutes.

All air entrainment tests were carried out at 50°C using ASTM test method D 3427.

Table 1

Air Entrainment Results for New Steam Turbine Oils

Oil Type	Description	Gas Bubble Separation Time (Min.) @ 50°C		
		Test 1	Test 2	Avg.
STO 32	Teresso 32 (Bruce NGS stock)	3.1	2.4	2.8
STO 32	Turbo 32 (Venezuelan Base Stock)	2.3	2.1	2.2
STO 32	Turbo 32 (Mideast Base Stock)	3.3	3.3	3.3
	Sunvis 916	7.1	6.6	6.9
STO 46	Endurance 46 (Blend 1903)*	5.6	4.7	5.2
STO 46	Teresso 46	8.3	6.7	7.5
STO 46	Turbo 46 (Venezuelan Base Stock)	3.3	3.5	3.4
STO 46	Turbo 46 (Mideast Base Stock)	3.1	3.3	3.2
STO 46	Sunvis 925	10.2	9.1	9.7

* This oil does not meet Ontario Hydro specification M-332-M-85. The remaining oils do.

Table 2

Air Entrainment and Foam Test Data*
for In-Service Steam Turbine Oils

Sample Description	Gas Bubble Separation Time @ 50°C (min)			Foam Test Volume	
	Test 1	Test 2	Avg.	After 5 min. Blowing (mL)	After 10 min. Standing (mL)
1. Nanticoke TGS - Unit 1	11.4	9.7	10.6	20	nil
2. Nanticoke TGS - Unit 2	10.4	9.6	10.0	250	nil
3. Nanticoke TGS - Unit 3	8.9	9.4	9.2	370	nil
4. Nanticoke TGS - Unit 4	10.2	8.9	9.6	380	nil
5. Nanticoke TGS - Unit 5	10.4	9.7	10.1	500	nil
6. Nanticoke TGS - Unit 6	11.8	10.8	11.3	470	nil
7. Nanticoke TGS - Unit 7	9.2	10.6	9.9	65	nil
8. Nanticoke TGS - Unit 8	9.7	9.8	9.8	50	nil
9. Thunder Bay TGS - Unit 2	7.4	8.0	7.7		
10. Thunder Bay TGS - Unit 3	8.0	8.0	8.0		
11. Atikokan TGS - Unit **	6.7	7.0	6.9		
12. Nanticoke TGS-Unit 1 BFP	8.8	9.9	9.4	900+	640
13. Nanticoke TGS-Unit 8 BFP	9.6	10.7	10.2	15	nil
14. Pickering NGS "A"-Unit 1	10.2	10.4	10.3		
15. Pickering NGS "A"-Unit 2	10.8	10.2	10.5		
16. Pickering NGS "A"-Unit 3	9.9	11.3	10.6		
17. Pickering NGS "A"-Unit 4	11.8	11.0	11.4		
18. Bruce NGS "B" - Unit **	5.0	4.6	4.8		

* Sample 18 is STO 32 grade, all other samples are STO 46 grade. Samples 12 and 13 are from boiler feed pumps, all others are from main turbine lubricating systems. Sampling dates: (1) Samples 1-8, 11-13: September, 1984, (2) Samples 9-10: October, 1984, (3) Samples 14-17: December 1984; and Sample 18: August, 1983.

** Unit number not given.

Table 3

New Seal Oils - Bruce Heavy Water Plant

Sample Description	Gas Bubble Separation Time (min)		
	Test 1	Test 2	Avg.
1. Gulf Paraflex H32*	2.5	2.3	2.4
2. Esso OH 241-010	2.7	2.5	2.6
3. Shell CL 1047 (Mideast Base Stock)*	2.5	1.9	2.2
4. Shell CL 1047 (Venezuelan Base Stock)	2.6	2.2	2.4

* Not qualified for use by Ontario Hydro.

Table 4

STO 46 Air Entrainment Results
Ontario Hydro/Imperial Oil Lubricant Exchange

Sample Description	Gas Bubble Separation Time at 50°C (minutes)			
	Ontario Hydro (a)	Imperial Oil (b)	Difference (a-b)	Reproducibility** $(1.3((a+b)/2)^{1/2})$
4423-230	5.0	5.9	-0.9	3.0
4423-231	3.7	3.3	+0.4	2.4
4372-722	7.5	6.6	+0.9	3.4

** The reproducibility calculation comes from ASTM D 3427. Difference values less than the corresponding reproducibility are acceptable ("not suspect").

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